



NASA SBIR 2022 Phase I Solicitation

Z2.01 Spacecraft Thermal Management

Lead Center: JSC

Participating Center(s): GRC, GSFC, JPL, MSFC

Scope Title

Spacecraft Thermal Management

Scope Description

NASA seeks new technologies that will facilitate low-mass and highly reliable thermal control systems for the exploration of our solar system. This solicitation specifically targets proposals for new technologies and methods that clearly address one of the following areas:

1. Lunar surface habitat thermal technologies
2. High-temperature heat acquisition and transport for nuclear electric propulsion (NEP)
3. Topology optimization of thermal control systems

These areas are considered of equal priority, and no award preference is expected for one area over another.

1. Lunar Surface Habitat Thermal Technology Development

NASA is seeking focused efforts to develop thermal control technologies that will enable crewed habitats for extended stays on the lunar surface. Technologies should address a gap associated to long-duration habitation on the lunar surface, where temperatures range from -193 Å°C or lower in shadow regions (including night) to 120Å°C at the equatorial subsolar point. Technologies are needed that allow a single mobile habitat to operate in all these environments. Technologies should address reduction in mass, volume, and power usage relative to current solutions. The addition of heaters can lead to increased vehicle mass due to additional power generation and storage requirements and is not considered a novel architecture approach. Proposed radiator technologies should also address micrometeoroid and orbital debris (MMOD) robustness and protection potential where appropriate.

Examples of other challenges to address in this area include the deposition of dust on radiators leading to degraded optical properties, contamination-insensitive evaporators/sublimators to enable long mission life, self-healing coolant tubes for MMOD-impact resilience, and passive gas traps for removing gas bubbles from internal thermal control system loops that use low-surface-tension nonwater coolants. Technologies should be suitable for use with habitats having variable heat loads averaging between 2 and 6 kW. All technologies should support a minimum operational duration of 5 years and be compatible with encountered environments.

Alternatively, technologies that utilize the conditions provided by the lunar environment to provide a critical function

may also be considered; for example, air-water separator technologies that leverage the gravity field of the lunar surface, or concepts that explore the viability of utilizing the lunar surface regolith to provide long-duration thermal control function. As appropriate, such systems should also address functional capability in the microgravity environment that will be experienced prior to lunar surface operations.

2. High-Temperature Heat Acquisition and Transport for Nuclear Electric Propulsion (NEP)

NASA is seeking the development of thermal transport systems for NEP. This application requires the transfer of large amounts of thermal energy from a nuclear reactor to a power conversion system. NASA desires a high-temperature heat transfer system capable of transferring 4 to 10 MW of thermal power from a nuclear reactor, at a supply temperature of 1,200 to 1,400 K and a flux on the order of 0.3 MW/m^2 with a goal of 1 MW/m^2 , to the hot-end heat exchangers of an electric power conversion system. The target distance for the power conversion system is 5 m from the reactor, but transport distances up to 10 m may be required. The system will need to be gamma- and neutron-radiation tolerant, be single-fault tolerant (a single leak should not render the system inoperable) and have an operating life of 15+ years. System mass and reliability should be addressed as part of the proposal.

Example solutions include, but are not limited to, liquid metal heat pipes or pumped fluid loops. Special consideration should be given to interfaces (both at the nuclear reactor and at the power conversion system) to maximize heat transfer. Integration with the reactor may include solutions that run through the reactor core. For integration with the power conversion system, a helium-xenon working fluid in a Brayton cycle system may be assumed but is not required.

3. Topology Optimization of Thermal Control Systems

Advanced design and manufacturing are rapidly transforming engineered systems. The advent of reliable additive manufacturing techniques coupled with robust optimization algorithms is facilitating the development of new high-performance systems. To date, the advanced design community has primarily focused on optimized structural systems that minimize mass and volume while meeting structural performance requirements. While some work has been done to develop advanced design tools for thermal control systems, considerable work remains to make it standard practice. This solicitation requests the development of a topology optimization (TO) tool that can optimize a thermal-fluid component (e.g., a heat exchanger). Specific goals include minimizing component (heat exchanger) mass, minimizing pressure drop, and maximizing heat transfer efficiency. Because of the inherent multiphysics characteristics of the problem (coupled structural/thermal/fluids behavior), proposals are encouraged to leverage existing TO software (e.g., see Watkins (2019) and other TO references below) that can already handle structural and thermal conduction optimization, and extend the code to handle systems that include single-phase laminar convective heat transfer.

This solicitation requests the development of TO software capable of minimizing heat exchanger mass while meeting envelope volume, heat transfer, and pressure drop targets. The initial target is optimization for laminar single-phase flow. An extended goal is to be able to optimize a heat exchanger for turbulent single-phase flow while accommodating manufacturing constraints to ensure the heat exchanger design is manufacturable.

Expected TRL or TRL Range at completion of the Project

3 to 5

Primary Technology Taxonomy

Level 1

TX 14 Thermal Management Systems

Level 2

TX 14.2 Thermal Control Components and Systems

Desired Deliverables of Phase I and Phase II

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- Analysis
 - Prototype
 - Hardware
 - Software

Desired Deliverables Description

Phase I awards in this area are expected to demonstrate analytical and/or empirical proof-of-concept results that demonstrate the ability of the organization to meet the goals stated in the solicitation.

At the conclusion of a Phase II contract, deliverables are expected to include a functioning prototype (or better) that demonstrates the potential to meet the performance goals of the technology or software. Any delivered math models should include supporting data that validates the assumptions used within the model.

State of the Art and Critical Gaps

These focus areas strive to reduce mass, volume, and power of a thermal control system in the next generation of robotic and human-class spacecraft and to enable long-term missions to the Moon and Mars. These improvements may come through either novel hardware solutions or modernization of software tools. The current state of the art in thermal control systems is vehicle power and mass impact of greater than 25 to 30% due to old technologies still in use. Furthermore, as missions become more variable (dormancy, environments, etc.), the need for intelligent design and control (both actively and passively) within the thermal control system becomes more apparent. For topology optimization (TO) in particular, it has become a well-established structural design tool, but it has yet to penetrate the thermal design community. Multiple research efforts have shown that TO of thermal-fluid systems is possible and can be successfully implemented to obtain optimized designs; however, a robust commercial code that is capable of doing this is yet to be demonstrated. Additionally, science payloads will continue to decrease in size, increase in power, and require precise temperature control, all of which cannot be readily provided by traditional thermal control methods due to vehicle-level impacts of overall performance, mass/volume, and power.

Relevance / Science Traceability

- Long-duration habitats (Moon, Mars, etc.).
- Lunar surface power.
- Mars transit vehicles.
- SmallSats/CubeSats.
- Rovers and surface mobility.
- Nuclear electric propulsion (NEP) systems.

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